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PATENT APPLICATION

MEMS STRUCTURE WITH MECHANICAL OVERDEFLECTION LIMITER

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MEMS STRUCTURE WITH MECHANICAL OVERDEFLECTION LIMITER

CROSS-REFERENCES TO RELATED APPLICATIONS

[01] NOT APPLICABLE

STATEMENT AS TO RIGHTS TO INVENTIONS MADE UNDER FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[02] NOT APPLICABLE

REFERENCE TO A "SEQUENCE LISTING," A TABLE, OR A COMPUTER PROGRAM LISTING APPENDIX SUBMITTED ON A COMPACT DISK.

[03] NOT APPLICABLE

BACKGROUND OF THE INVENTION

[04] This invention relates to electro-mechanical components such as micro electrical mechanical system (MEMS) devices or MEMS arrays and particularly to electrostatically-actuated electro-mechanical components wherein undesired deflection of movable elements due to nonlinear attractive effect may be controlled, preventing device failure. Components constructed according to the invention are MEMS mirror arrays or other micromachined elements.

[05] Conventional MEMS array structures comprise Silicon on Insulator (SOI) array structures on which is fabricated an integrated electrode array. One of the problems encountered is device failure due to uncontrolled electrostatic deflection of the movable element of the device resulting in contact with the underlying substrate during operation due to overvoltage drive or inertial ringing of the device. Failure mechanisms include voltage breakdown, mechanical stiction or welding, and mechanical deformation of hinge elements. Anyone one of these failures can render a cell useless and severely hamper the usefulness of an array.

[06] In a commonly-owned co-pending patent application Serial No. 10/128,368 filed April 23, 2002, the structure of a MEMS device is disclosed which employs a form of a stop

based on the present invention. The co-pending application is not prior art to the present invention.

[07] In U.S. Patent No. 6,315,423 claiming a priority date of July 13, 1999, one form of mechanical stop is disclosed for a MEMS device which has high angles of displacement with highly compliant hinges. The travel stops therein are for overswing and x-axis shock protection, since the hinge design therein allows for large desired rotational motions as well as undesired multi-axis translational motions. Hence the travel stops therein are not one-dimensional stops.

[08] A solution is needed that limits the maximum deflection of the MEMS device due to inherent electrostatic parallel plate instability without compromising device performance or manufacturability.

SUMMARY OF THE INVENTION

[09] According to the invention, a MEMS device is provided having a fixed element and a movable element wherein one of the fixed element and the movable element has at least one radially-extended stop or overdeflection limiter. A fixed overlayer plate forms an aperture. The aperture is sized to minimize vignetting and may be beveled on the margin. Overdeflection limitation occurs during deflection before the movable element can impinge on an underlying electrode. The overdeflection limiter may be conveniently placed adjacent a gimbaled hinge.

[10] The mechanical stop may be a plate mounted to the top of a conventional MEMS structure or integrated into a three layer MEMS structure or two two-layer MEMS structures combined. The invention will be better understood by reference to the following detailed description in connection with the accompanying illustrations.

BRIEF DESCRIPTION OF THE DRAWINGS

[11] Figure 1 is a perspective view in cutaway of a first embodiment according to the invention of a double-gimbaled mirror with a top mounted overhang stop layer.

[12] Figure 2 is a top view of a double gimbaled mirror with mechanical stop tabs extending from the mirror.

[13] Figure 3 is a side cross-sectional view of a single array element with a flipped SOI overhang mounted on a standoff.

[14] Figure 4 is a side cross-sectional view of a single array element with an overhang formed in a single process step as a bevel.

[15] Figure 5 is a perspective view of the element of Figure 4.

[16] Figure 6 is a side cross-sectional view of a single array element with an overhang of multiple bonded wafers.

[17] Figure 7 is a perspective view in cutaway of a first embodiment according to the invention of a double-gimbaled mirror with a top mounted overhang stop layer.

DETAILED DESCRIPTION OF THE INVENTION

[18] Referring to Figure 1 there is shown a perspective view in cutaway of a first embodiment of a single array element 10 of a MEMS array according to the invention. A mirror 12 is mounted on a first pair of hinges (Figure 2) 14, 16 to a gimbal 18. The gimbal 18 is connected by a second pair of hinges 20, 22 having one degree of freedom to a frame 24, more particularly to a cantilever 26 of the frame 24 wherein an oxide layer 25 (Figure 3) is provided for bonding and etch stop during manufacturing. The oxide layer 24 is typically on the order of only one micron thick. The nature of the frame construction is immaterial so long as it provides support. For example, surface micromachine processes and bulk micromachine processes can be employed to construct a frame without departing from the spirit and scope of the invention. According to the invention, an overhang 28 is provided which serves as a mechanical stop against rotation of the mirror 12. The overhang 28 is typically mounted above the mirror 12 (i.e., outside the electrode cavity) as part of a cap 30. In Figure 1, tab extensions 32, 34 extend from the mirror 12 adjacent the second hinge pair 20, 22. Referring to Figure 7, an alternative and less desirable embodiment employs tab extensions 32A, 34A which extend from the overhang 28 to encounter the edge of the mirror 12. While the tab extension allow for reduced mirror mass, they potentially vignette the beam to result in signal loss.

[19] The frame 24 spaces the mirror from electrodes 36-39 mounted on a substrate 40. A dielectric 42 spaces the frame 24 from the substrate 40, and a plurality of standoffs 44, of which only one is shown in Figures 1 or 7) separate the cap 30 from the frame. Depending on the design of over-rotation sensors, the standoffs 44 can be either insulative or conductive. Insulative standoffs are useful if there is a circuit to be formed that senses contact between the mirror and the overhang indicating overdeflection. Conductive standoffs make it easier to construct a conductive cap 30, thus maintaining the mirror 12 and the cap 30 at equal potential.

[20] Figure 3 illustrates in cross section a view of Figure 1 or 2 along sight line 3-3 through tabs 32, 34, gimbal 18 and cantilever 26. The overhang 28 is an aperture plate

mounted on standoffs 44, which in this embodiment is a separately-formed layer formed on the cap 30. The cap 30 and overhang 28 are typically SOI structures (Silicon on Insulator where two different silicon layers are typically bonded together but separated by an oxide) which are "flipped" after fabrication and mounted by an appropriate adhesive such as an epoxy to standoffs 44, which could be cylinders, beads or the like. Alternatively, the top layer of the mirror 12 on its frame 24 could be etched to match a complementary cross etch in the mating face of the overhang 28 to assure accurate seating when beads are used as spacers. A KOH etch technique could be used wherein the crystal structures of the respective SOI chips are cross-ways to one another.

[21] Figure 4 is a side cross-sectional view of a single array element along sight line 4-4 with a typical deep KOH etch along exposed crystal planes to form an aperture 30A . The aperture 30A (Figure 5) is a rectangle with exposed facets 52-56, etc. It can be attached in the same manner as the structure of Figure 3 with an appropriate adhesive to standoffs 44.

[22] Flipped SOI has advantanges over conventional KOH fabrication of an aperture, since it permits relatively loose manufacturing tolerances of lithography, thus allowing the tabs 32, 34 to be reliably shorter. It should be noted, however, that polishing and spacing are critical to the required tolerances.

[23] Figure 6 is a side cross-sectional view of a single array element with multiple bonds of SOI, so-called triple-stacked SOI. A dielectric 42 separates electrodes 38, 39 from the frame 40, and an oxide layer 25 is disposed between the frame 40 and the layer forming the mirror 12. A further oxide layer 27 is disposed between the layer of the mirror 12 and a further silicon cap 30, which in this case is step etched (before bonding) to form a shelf 31. The cap 30 is bonded to the layer of the mirror 12 at the oxide layer 27 after the oxidation and release step of the manufacturing process. This structure was disclosed but not claimed in a co-pending patent application which is not prior art. No extra assembly is required, since the triple SOI manufacturing step is an integrated process. However, it may be difficult to maintain isolation of mechanical stop layer from the stand-off layer due to the thin oxide.

[24] The invention has been explained with reference to specific embodiments. Other embodiments will be evident to those of skill in the art. It is therefore not intended that this invention be limited, except as indicated by the appended claims.